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Station Platform-Railcar Threshold Gap Study

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Engineering Center (VAREC)
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March 1982
Final Report

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16. Abstract
This study was conducted for the Transportation Systems Center by the Veterans Administration Rehabilitation Engineering Center (VAREC). It is part of a program to improve railcar accessibility for the handicapped riders. The purpose of this investigation by VAREC was to gather data on: 1) the acceptable range of maximum gaps, which are various horizontal and vertical spacings in combination, which can be safely crossed by individuals in manually propelled or powered wheelchairs; 2) suitable techniques for safely and independently crossing such gaps in a wheelchair; 3) the abilities of persons in wheelchairs with different disabilities to safely and independently cross the gaps; and 4) what effects repeatedly crossing these gaps may have on the structural integrity (durability and life expectancy) of wheelchairs. Actual rail car-station platform gaps measured in the course of the 321 studies varied from less than two inches wide and no vertical height difference to over six inches wide and a three or four-inch vertical differential. The results of these tests could be used in developing maximum vertical and horizontal gap criteria, and in assuming the need and operational feasibility of station-located or vehicle-mounted "gap fillers". This report examines the procedures used in performing the experiment, the subject profiles, and a summarization of the test results. There are two conclusions drawn from this study: 1) special training in gapcrossing techniques will assist handicapped passengers in using rail transit and 2) development of improved wheelchairs with equipment to overcome vertical barriers should make the transit environment more accessible to the handicapped.

17. Key Words
Accessibility; Elderly; Gaps; Handicapped; Horizontal Barriers; Railcar Accessibility; Vertical Barriers

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PREFACE

This study was conducted for the U.S. Department of Transportation's Systems Center by the Veterans Administration Rehabilitation Engineering Center (VAREC). It is part of a program to improve railcar accessibility for the handicapped patron. This project was sponsored by the Office of Rail and Construction Technology, Office of Technology Development and Deployment, Urban Mass Transportation Administration. It was conceived and managed by Jeffrey Mora and Ronald Kangas of that office, Donald Sussman and Stuart Palonen of the Transportation Systems Center.

Our thanks are extended to the Eastern Paralyzed Veterans Association (EPVA) which provided the eleven subjects in the first group of test volunteers, who donated their time and effort to come to VAREC and participate in the tests. Special thanks are extended to Mr. Kurt Eisenmann, research director of EPVA, who assembled the test volunteers, Mr. Terence J. Moakley, Barrier-Free Design Director of EPVA, who operationally tested several experimental wheelchairs in addition to participating in the gap crossing tests.

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in ≡ 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F

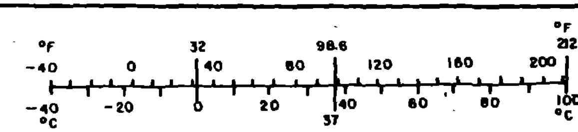


TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

I. INTRODUCTION

The "321" Rapid, Light, and Commuter Rail accessibility cost and technical studies* conducted by consultants, UMTA, transit operators, and the U.S. Department of Transportation (1979-1981) raised questions regarding the magnitude of the gap between station platforms and railcar floors (or thresholds), and the ability of persons of varying handicaps to traverse these vertical and horizontal discontinuities. As a result of these questions, the Veterans Administration was asked to conduct a series of empirical tests to determine the ability of persons in wheelchairs to traverse a range of actual vertical and horizontal "gaps" on a test device. Actual rail car-station platform gaps measured in the course of the 321 Studies varied from less than 2 inches wide and no vertical height difference to over 6 inches wide and a 3- or 4-inch vertical differential.

The result of these tests could be used in developing maximum vertical and horizontal gap criteria, and in assessing the need and operational feasibility of station-located or vehicle-mounted "gap fillers."

Jeffrey Mora
Urban Mass Transportation Administration
Office of Rail & Construction Technology

*321 refers to Section 321 of the Surface Transportation Assistance Act of 1978.

II. PURPOSE

The purpose of this investigation by the Veterans Administration was to gather data on:

(a) The acceptable range of maximum gaps (various horizontal and vertical spacings in combination) which can be safely crossed by individuals in manually propelled or powered wheelchairs.

(b) Suitable techniques for safely and independently crossing such gaps in a wheelchair.

(c) The abilities of persons in wheelchairs with different disabilities safely and independently to cross the gaps.

(d) The effects crossing these gaps repeatedly may have on the structural integrity (durability and life expectancy) of wheelchairs.

III. PROCEDURE

1. Equipment

Achieving the objectives outlined in Section II, (a) through (d) above, required test equipment for laboratory simulation of horizontal and vertical gap dimensions between station platforms and a vehicle door threshold. A Portable Gap Simulator was developed for possible data collection at several local VA Medical Centers. It permitted a reasonable range of gap and vertical height adjustment.

Since nearly all test subjects preferred to use their personal wheelchairs during the experiments with the Gap Simulator, there were no specific requirements on type, size or style of wheelchair. It was felt that the use of personal wheelchairs on the Gap Simulator increases the validity of the test results by controlling possible training or learning variables.

Testing wheelchairs for durability and life expectancy was done by use of a Test Carousel. The wheelchairs were to be driven 3600 times over a test course including a gap having maximum horizontal and vertical dimensions as previously established by experimentation on the Gap Simulator. Frequent measurements of changes in the drive wheels (wheel rim lateral distortion or runout, wheel concentricity, bearing wear, spoke changes) were to be taken to assess the degradation of the wheels as the test program progresses. Damage observed in other parts of the wheelchair were also recorded. Measurements of changes in drive wheels were made after 50, 100, 200, 400, 800, 1600, and 3600 test cycles. The test was halted if substantial damage to the wheelchair became evident.

2. Safety

Appropriate measures to insure the safety of test subjects and laboratory personnel were in use throughout the project. The safety system consisted of an optional restraining belt at abdominal height to keep an individual in the wheelchair. In addition, two trained experimenters were always close by whenever subjects passed over the gaps.

3. Subjects

Test subjects were wheelchair-bound volunteers, who agreed to participate in these laboratory experiments. Veterans from within the VA system (hospitals, clinics, etc.) as well as other organizations (Paralyzed Veterans of America, etc.) were asked to participate.

Wheelchair mobility and user technique to cross a variety of simulated rapid rail platform-vehicle floor misalignments, or so-called "gaps" was demonstrated by the performance of twenty-six (26) arbitrarily selected wheelchair-bound test subjects. The population tested was subdivided into two (2) test groups: 1) eleven (11) test subjects were examined at the VA Rehabilitation Engineering Center, New York, and 2) fifteen (15) test subjects examined at the VA Medical Center, New York. The first group tested at VAREC were all members of the Eastern Paralyzed Veterans Association (EPVA), who graciously consented to participate in the joint DOT/VAREC study. These were all totally self-sufficient active individuals, who generally had little difficulty in completing the exercises on the gap-simulator. The second group tested were in-patients at the VA Medical Center, New York, who obviously were less experienced in the use and control of their wheelchairs. We would like to express our thanks to both test groups.

IV. LABORATORY TEST

The portable gap-simulator apparatus built at the VA Rehabilitation Engineering Center, New York, was used in trials with twenty-six

(26) test subjects. The gap-simulator (shown in Fig. 1) has two platforms, one representing the station platform, the other the rail vehicle floor. These two platforms can be separated horizontally from 2.0 inches to 5.0 inches, and offset vertically from 1.0 inch to 4.0 inches to simulate a variety of gap combinations. The test conditions established for the study are shown in Table 1.

Nearly all wheelchair users seemed to prefer travelling forward when moving from a lower to a higher platform, presumably entering through the door of a rail vehicle. The method of testing for each combination of horizontal and vertical adjustment of the gap-simulator was as follows:

1. Position the wheelchair on the lower platform so it is close to the gap edge of the higher platform, considering the possibility of the interference of both footrest extensions.
2. Perform a "wheelie" just big enough to jump both caster-wheels over the higher platform edge. Some skill in wheelchair use is required, since both the wheelchair and its occupant are momentarily unstable.
3. Advance drive-wheels to edge of higher platform, and raise wheelchair fully onto platform.
4. Descending from higher platform by traveling backward, i.e., drive-wheels first. Caution was exercised not to entrap caster wheels in gap during descending maneuver.

Figure 2 shows a diagram of the wheelchair maneuver required to cross gap in the forward direction.

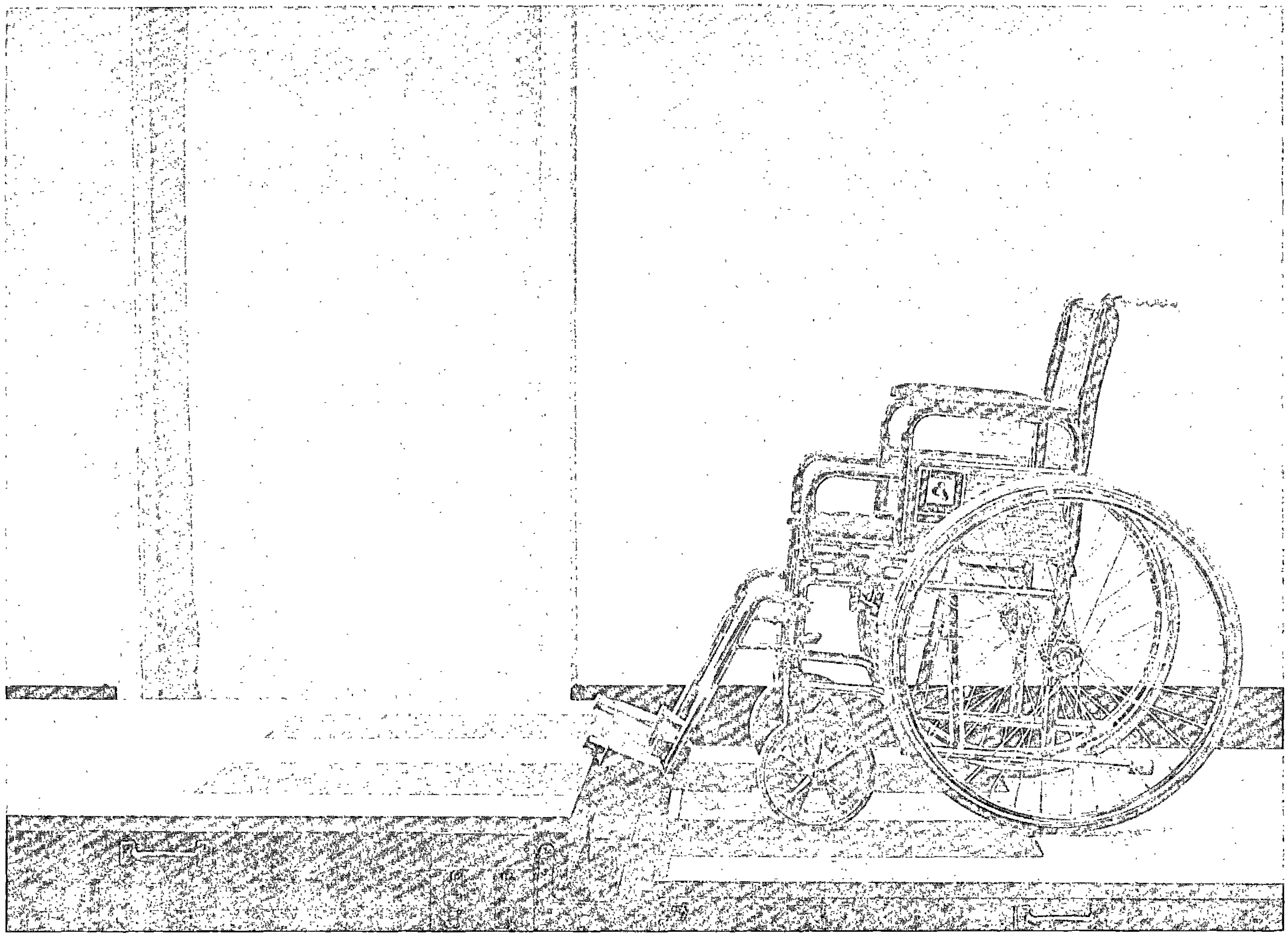
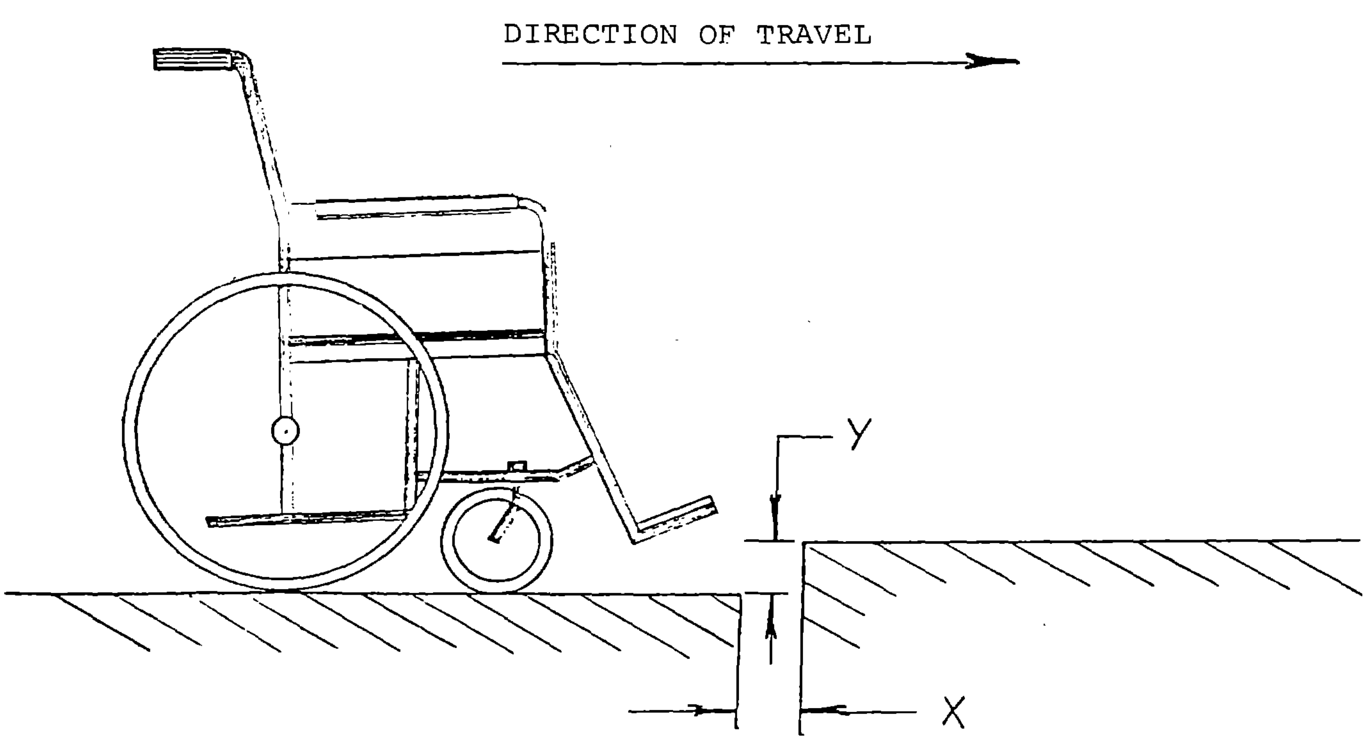


FIGURE 1 VAREC GAP SIMULATOR

TABLE 1. TEST CONDITIONS

GAP DESIGNATION	HORIZONTAL (X INCHES)	VERTICAL (Y INCHES)
A	2.0	1.0
B	3.0	1.0
C	4.0	1.0
D	5.0	1.0
E	2.0	2.0
F	3.0	2.0
G	4.0	2.0
H	5.0	2.0
I	2.0	3.0
J	3.0	3.0
K	4.0	3.0
L	5.0	3.0
M	2.0	4.0
N	3.0	4.0
O	4.0	4.0
P	5.0	4.0



V. TEST RESULTS

All 26 test subjects preferred to use their personal wheelchairs during experiments with the gap-simulator. The study was limited to users of manual wheelchairs, since powered wheelchairs cannot operate safely under the test conditions shown in Table 1. Powered wheelchairs intended for gap crossing would need a specially designed curb-climbing device, suitable for independent control by the wheelchair occupant. In Table 2, a summary of test results is presented. Specifically, the following should be noted:

1. The first group of eleven (11) test subjects are active and highly experienced wheelchair users. Their observed skill level ranges from medium to high. On the basis of their performance, most of these individuals would have little or no difficulty in crossing reasonable gaps in rapid, light, or commuter rail transit. A curious event was the failure of two of these subjects to negotiate horizontal and vertical gaps of 2 and 4 inches and 3 and 4 inches respectively, although they were able to handle both smaller and larger gaps. We attribute this phenomenon to fatigue or maneuvering aberrations.
2. All eleven (11) test subjects prefer pneumatic wheels for greater personal comfort and ease of operation of the wheelchair.
3. The second group of fifteen (15) test subjects uniformly lacked skill and technique in the use of a wheelchair. These individuals had all been confined

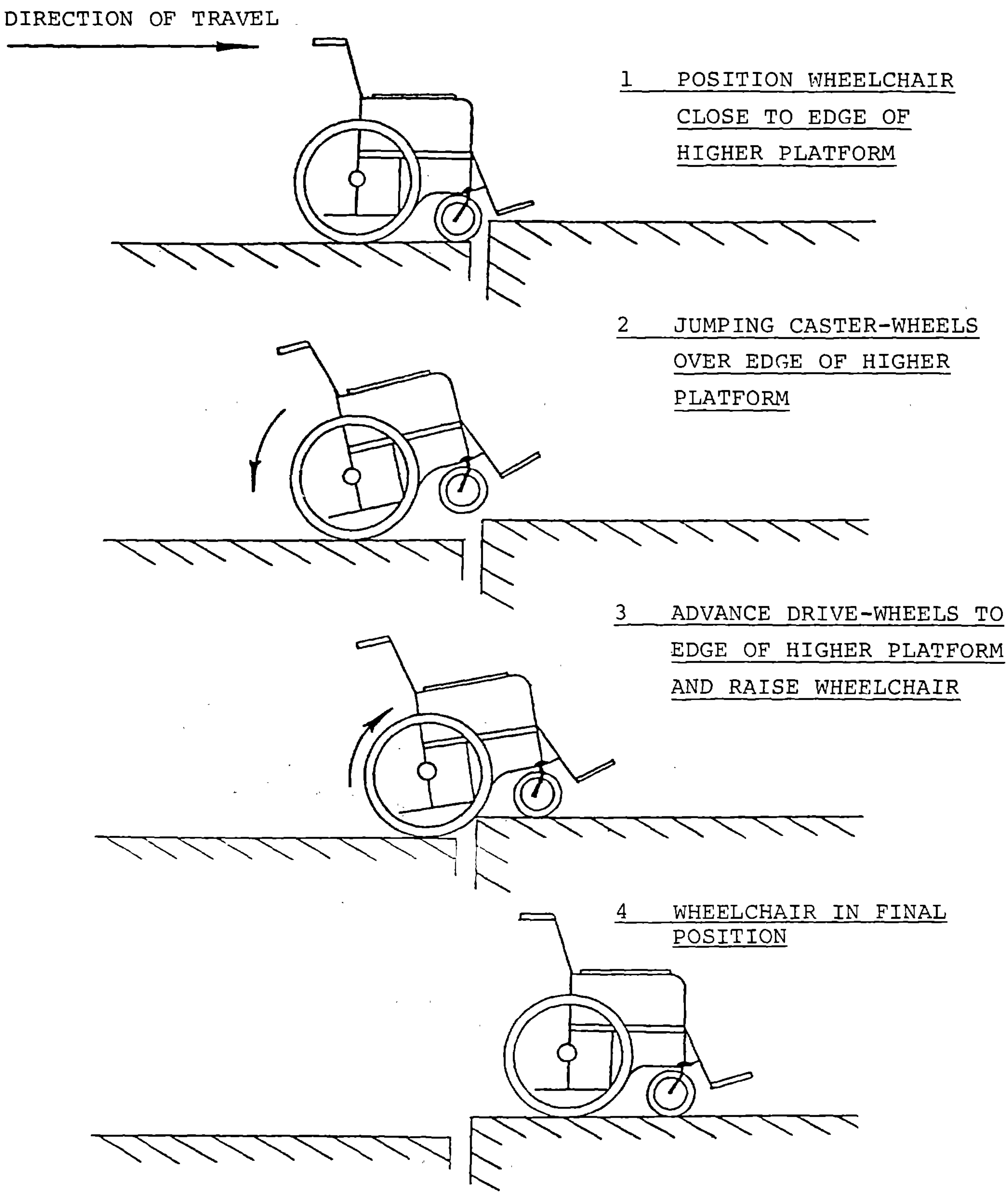


FIGURE 2 WHEELCHAIR MANEUVER TO CROSS GAP

TABLE 2. SUMMARY OF TEST RESULTS

SUBJ. NO.	AGE	SEX	DISABILITY	WHEELCHAIR DESCRIPTION	WT. (LBS)	OCCUPANT & W/C WT.	GAPS WHICH COULD NOT BE CROSSED		OBSERVED SKILL LEVEL
							FORWARDS	BACKWARDS	
1	48	M	Para. T-12	E&J, Pneu. Tires	42	252			High
2	28	M	Dbl. A/K Amp.	SS, Pneu. Tires	42	269			High
3	31	M	Quad. C-7	SS, Pneu. Tires	42	213			Medium
4	32	M	Para. T-10	SS, Pneu. Tires	42	223			High
5	62	M	Polio	E&J, Pneu. Tires	48	243			Medium
6	35	M	Quad. C-6	E&J, Pneu. Tires	34	215	I-P	I-P	Medium
7	32	M	Para. T-1	E&J, Pneu. Tires	50	209			High
8	34	M	Para. T-10	SS, Pneu. Tires	45	209			High
9	47	M	MS, T-10	SS, Pneu. Tires	38	178			High
10	35	M	Para. T-10	SS, Pneu. Tires	42	175			High
11	40	M	Para. T-6	E&J, Pneu. Tires	35	225			High
12	61	M	Rt. leg B/K Amp.	E&J, Solid Tires	52	242	C-P	C-P	Low
13	30	M	Recent SCI	E&J, Solid Tires	52	186	D-P	D-P	Low
14	23	M	Recent SCI	E&J, Solid Tires	52	291	B-P	B-P	Low
15	80	M	Hemiplegic	E&J, Solid Tires	52	197	A-P	A-P	Low
16	43	M	Hemiplegic	Mobilaid, Solid Tires	51	312	A-P	A-P	Low
17	89	M	Dbl. B/K Amp.	Rolls, Solid Tires	54	234	A-P	A-P	Low
18	64	M	Dbl. B/K Amp.	E&J, Solid Tires	52	200	C-P	C-P	Low
19	59	M	Recent SCI	E&J, Solid Tires	52	253	A-P	A-P	Low
20	63	M	Hemiplegic	Mobilaid, Solid Tires	51	190	A-P	A-P	Low
21	52	M	Recent SCI	E&J, Solid Tires	52	182	D-P	D-P	Low
22	55	M	Hemiplegic	Mobilaid, Solid Tires	51	218	A-P	A-P	Low
23	50	M	Hemiplegic	E&J, Solid Tires	52	188	B-P	B-P	Low
24	72	M	Hemiplegic	Mobilaid, Solid Tires	51	170	B-P	B-P	Low
25	39	M	Recent SCI	E&J, Solid Tires	52	197	C-P	C-P	Low
26	77	M	Hemiplegic	Mobilaid, Solid Tires	51	215	A-P	A-P	Low

SUPPLEMENT TO TABLE 2.

DISABILITY ABBREVIATIONS USED

T = Thoracic Spinal Cord Injury

C = Cervical Spinal Cord Injury

number following indicates vertabrae, e.g., T-12 indicates injury at the 12th thoracic vertabrae

SCI = having sustained some degree of spinal cord injury

MS = Multiple Sclerosis

A/K = Amputation above knee

B/K = Amputation below knee

WHEELCHAIR MANUFACTURERS

E&J = Everest and Jennings

SS = Stainless Specialties

Mobilaid

Rolls

GAP DESIGNATIONS

see Table 1

to wheelchairs within the past 6 - 12 months, and had no real experience in the operation of a wheelchair outside the hospital environment. Accordingly, their observed skill level was uniformly low. It would not appear likely that any test subject from this group could use a rail transit system independently.

Figures 3-5 show a typical sequence of tests with the gap-simulator.

The durability and life expectancy of a wide variety of conventional wheelchairs used in gap crossing would be difficult to predict. However, a general degradation of mechanical components and hardware, e.g., bearings, spokes, wheel rims, axles, etc. usually occurs with atypical use of a wheelchair. The repeated impact between wheelchair and platform or vehicle floor level during gap crossing could easily result in some damage over a period of time. For example, as shown in Figure 6, severe distortion of wheel rims to the point where the wheelchair is no longer operational. The damage occured gradually over a period of 3600 test cycles. The wheelchair including a 150 lb. anthropometric dummy descended from a curb height of approx. 6 inches, drive-wheels going first. This descent maneuver is nearly identical to the work done on the gap-simulator.

VI. CONCLUSIONS AND RECOMMENDATIONS

The conclusions drawn from this study are based on data collected, and our general observations of twenty-six (26) wheelchair-bound test subjects using the gap-simulator. It appears that poor

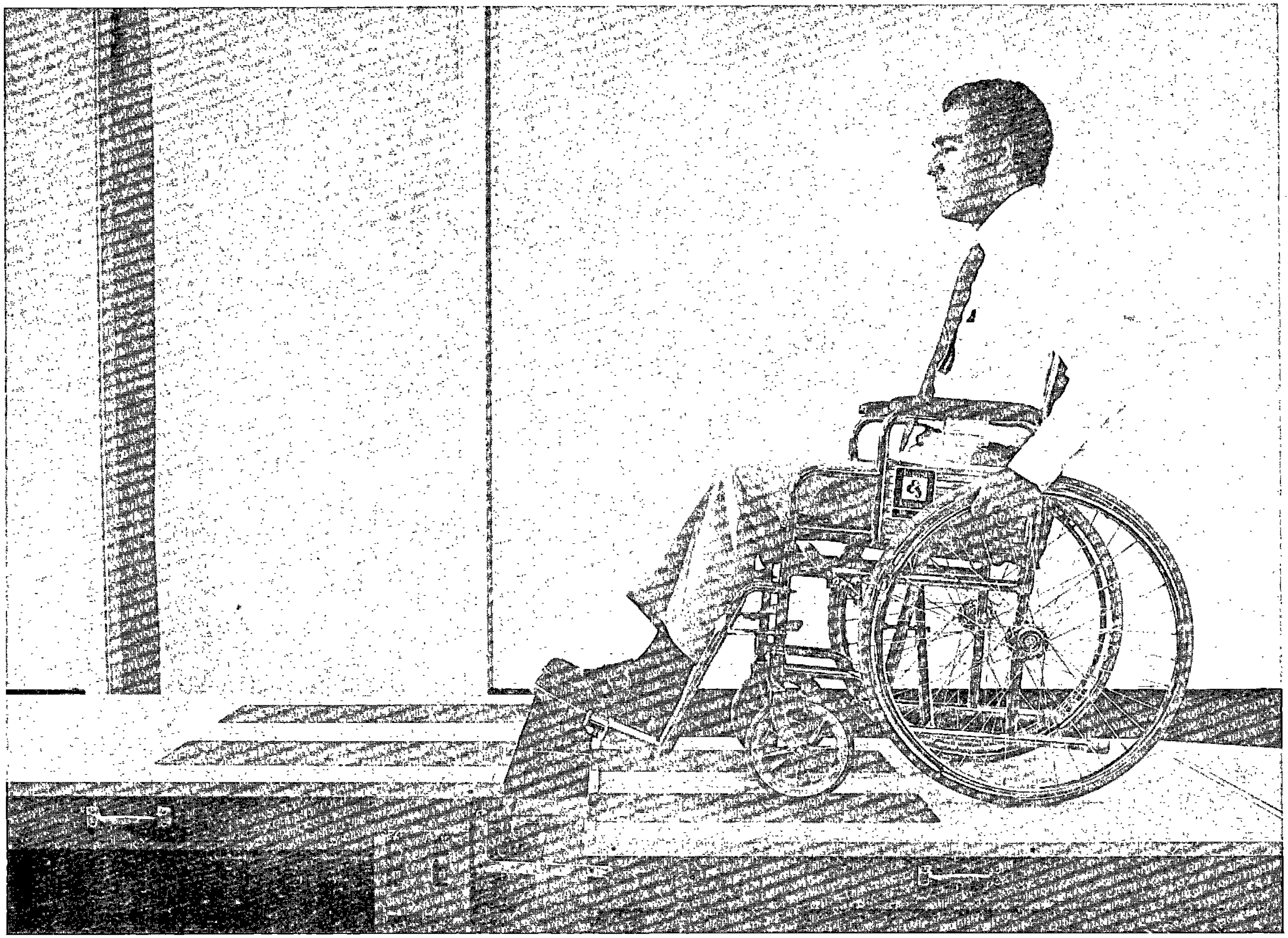


FIGURE 3 GAP CROSSING TEST STARTING POSITION OF W/C

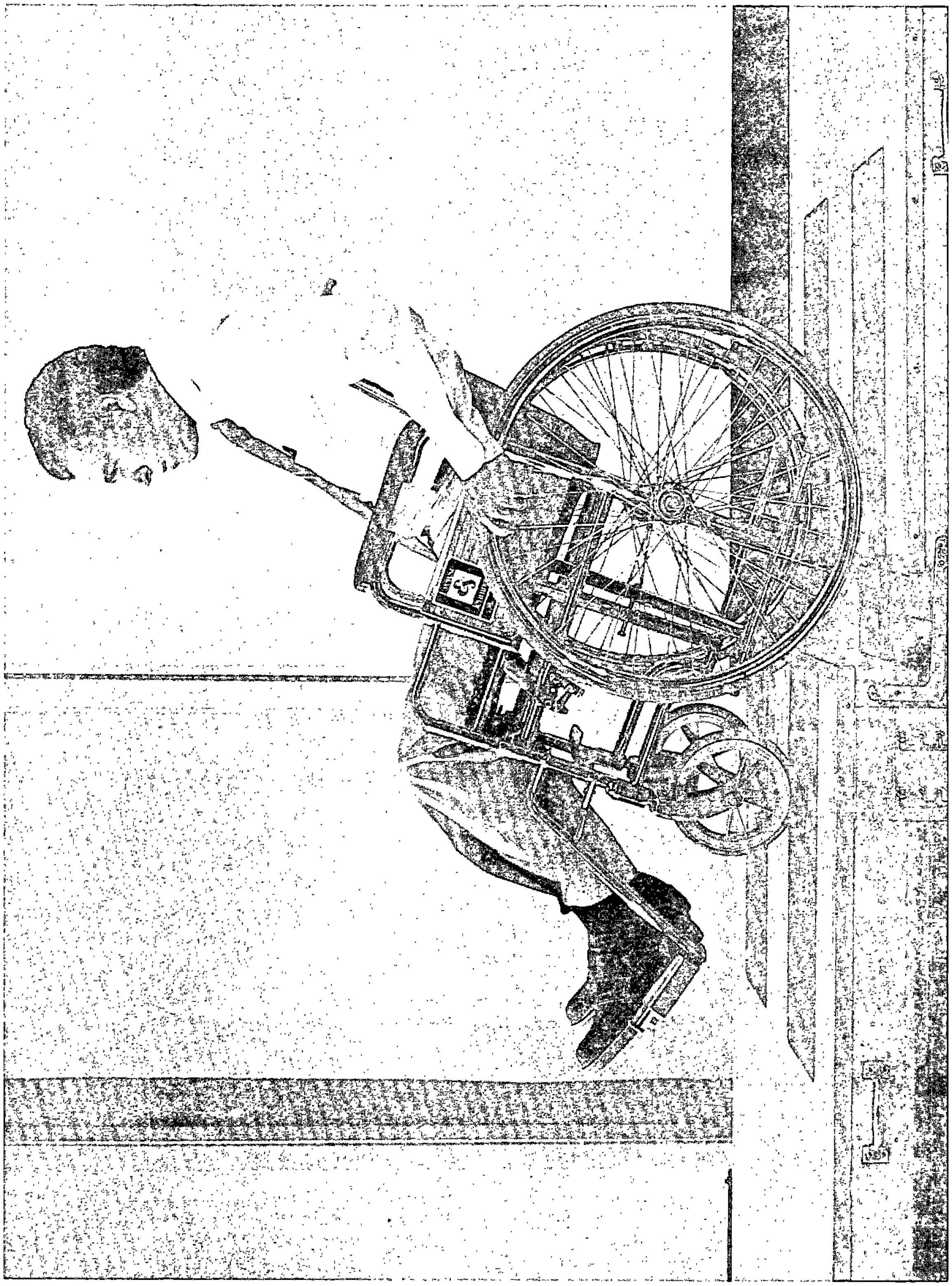


FIGURE 4 GAP CROSSING TEST INTERMEDIATE POSITION OF W/C

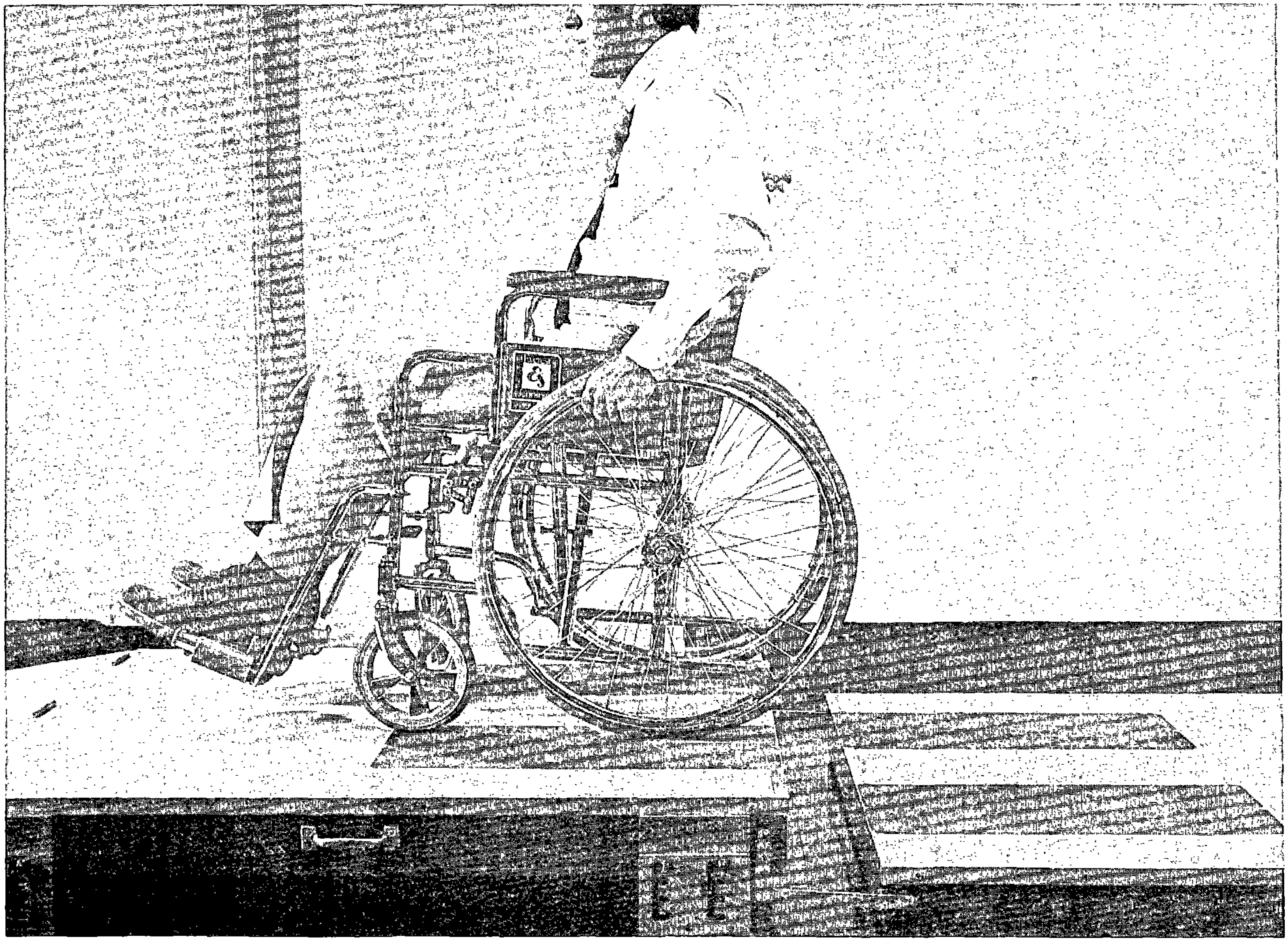


FIGURE 5 GAP CROSSING TEST FINAL POSITION OF W/C

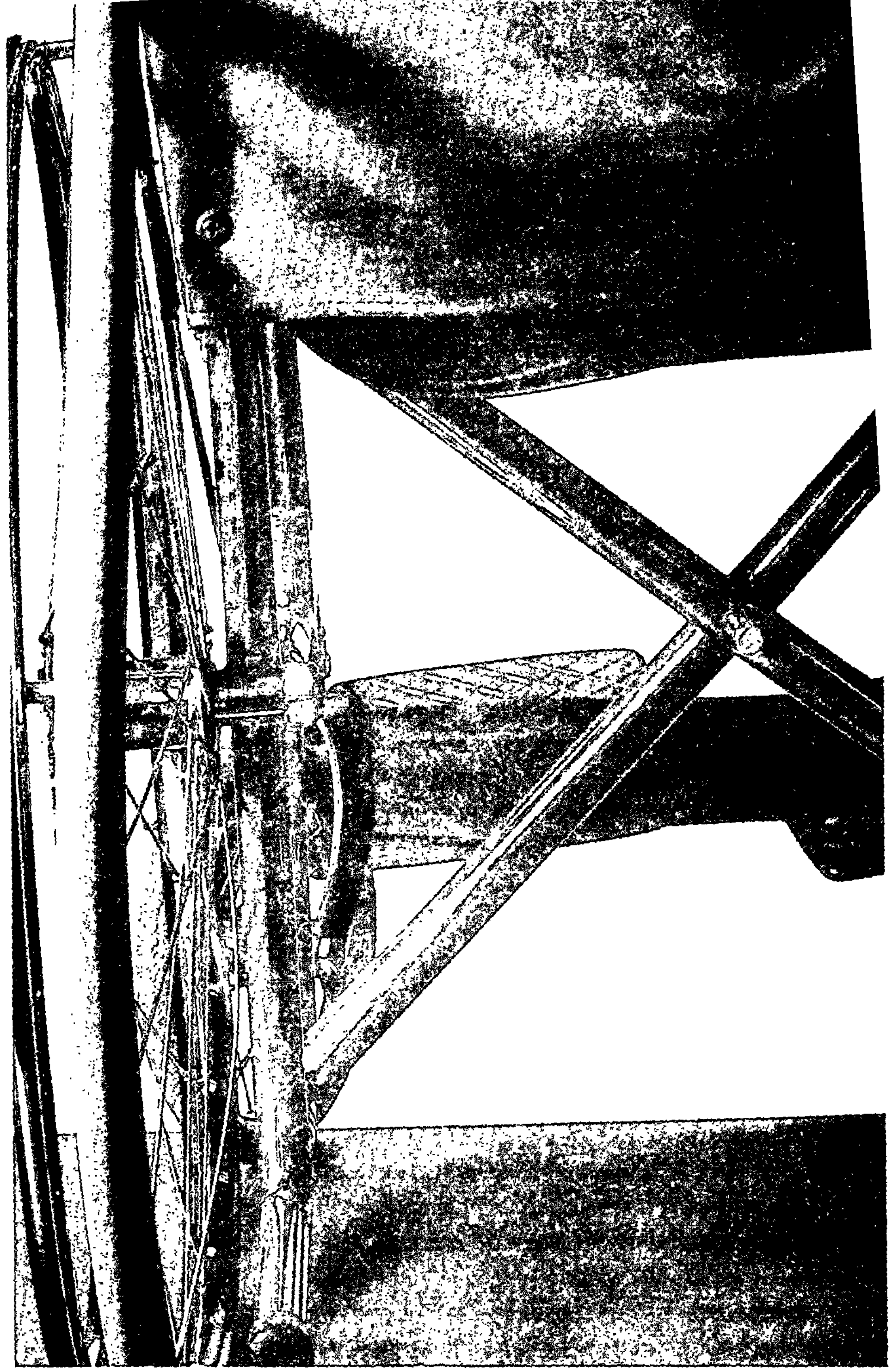


FIGURE 6 DAMAGE TO W/C AFTER 3600 TEST CYCLES

technique in wheelchair use directly relates to the low level of achievement of the fifteen (15) individuals tested at VAMC, New York. The type or severity of disability of these wheelchair users alone does not seem significant. They all performed poorly, regardless of their level of disability.

On the other hand, the highly experienced group of eleven (11) wheelchair users tested at the VA Rehabilitation Engineering Center, New York had nearly full control of the wheelchairs throughout the test. The following recommendations are offered:

1. The need of a training program to teach wheelchair-bound individuals special techniques in gap crossing, etc., would be essential in making rail transit accessible to the handicapped. Rehabilitation centers could provide the special training needed by some otherwise self-sufficient wheelchair users.
2. There is a need for more research and development of special wheelchairs for greater mobility by the handicapped. The compatibility of manual and powered wheelchair systems and the rail transit environment must be clearly understood. An example of on-going R&D is the University of Virginia "Grasshopper" experimental wheelchair shown in Figures 7-8.
3. Special attention should be given to currently available curb-climbing devices for both manual and powered wheelchairs. Gap crossing with powered wheelchairs would rely a great deal on dependable and easily operated special devices. A cross-section of typical

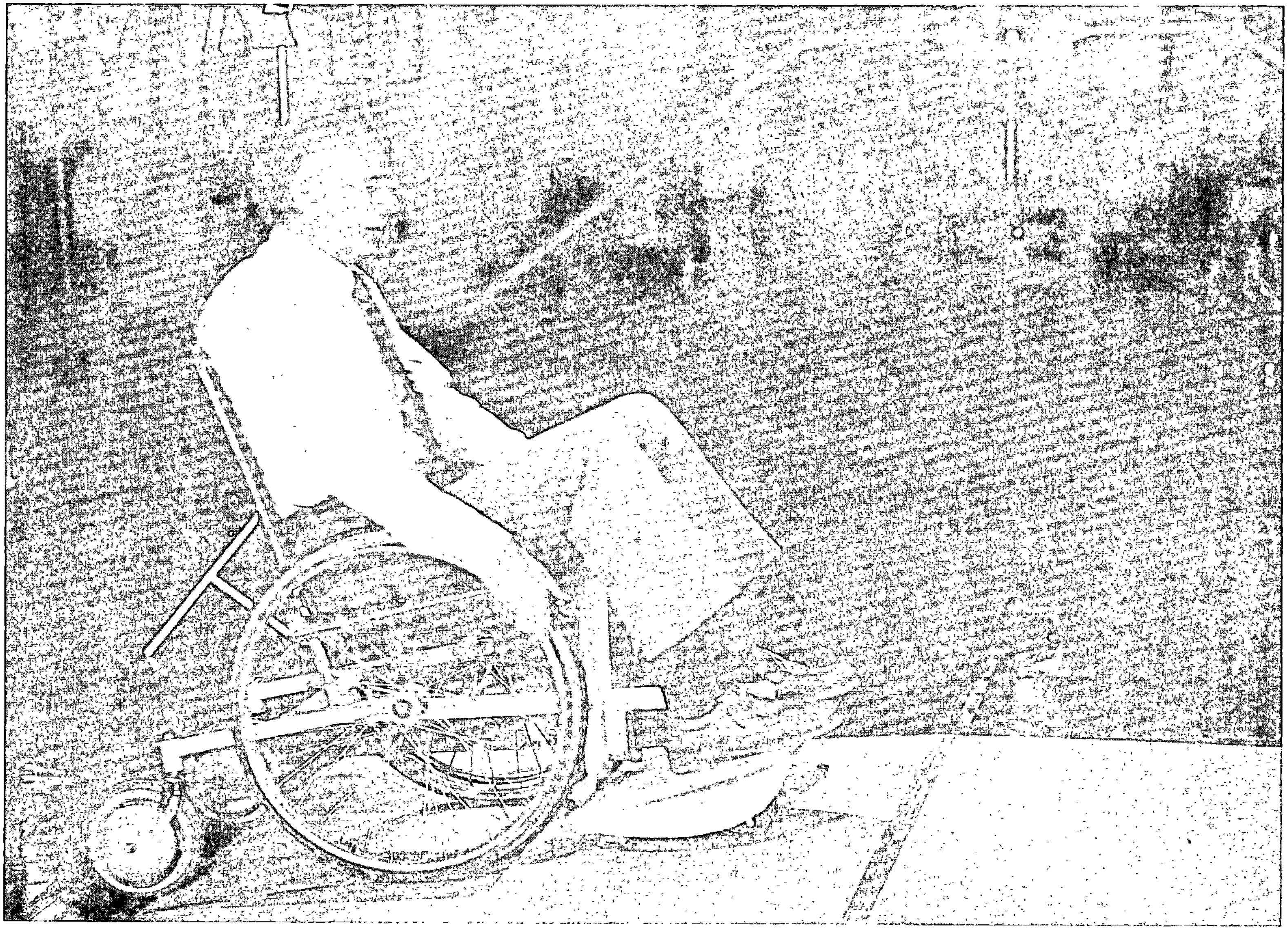


FIGURE 7 UV "GRASSHOPPER" EXPERIMENTAL W/C

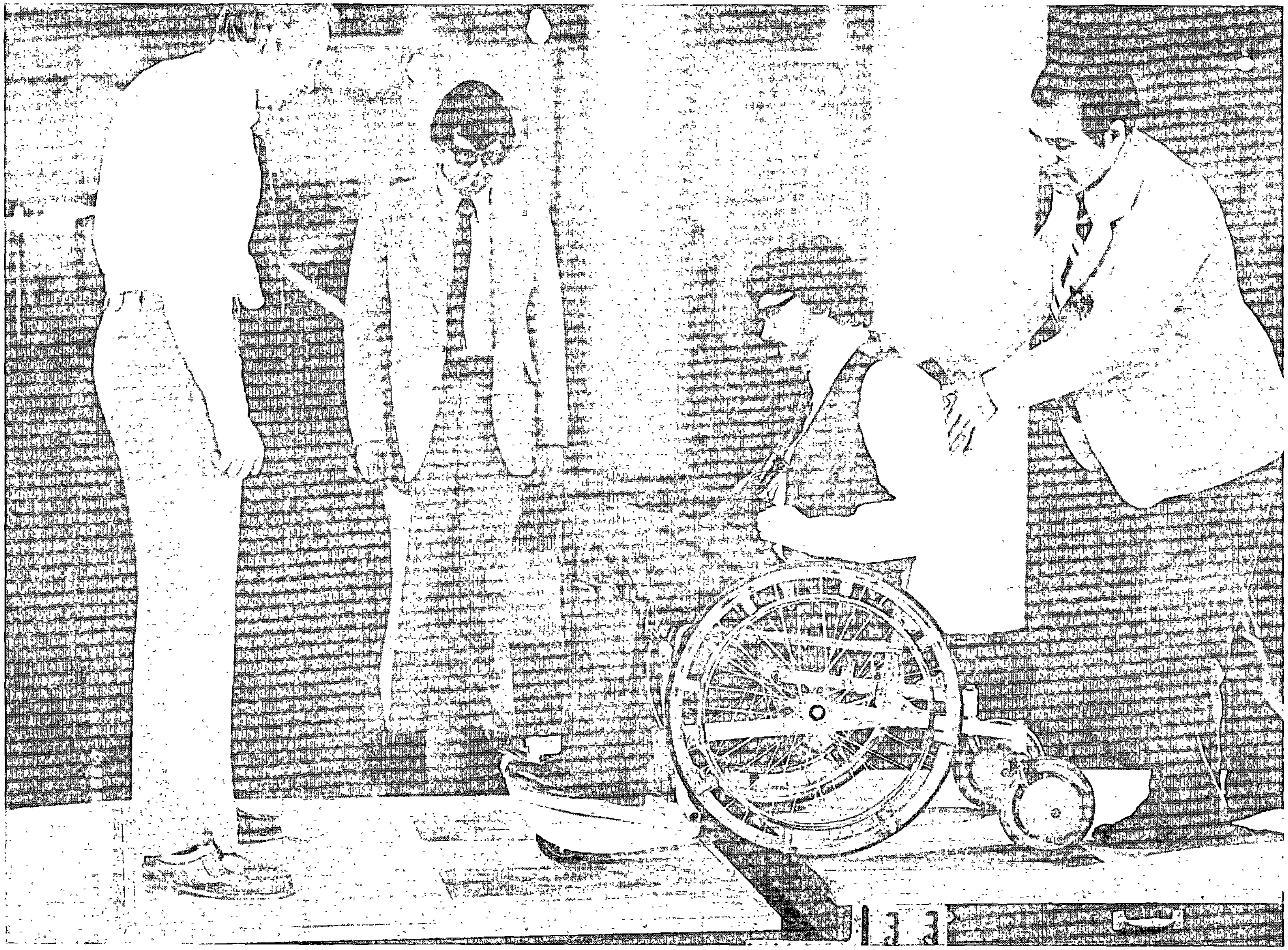


FIGURE 8 UV "GRASSHOPPER" EXPERIMENTAL W/C

curb-climbing devices for both manual and powered wheelchairs is shown in Figures 9-14. These devices present the current "state-of-the-art" of curb-climbing devices, some of which might be useful to overcome obstacles found in rapid rail transit.

Figure 9	Aztec, dropback dolly, curb-climbing device
Figure 10	Sun Industries wheelchair and curb-climbing device
Figure 11	Proreco curb-climbing device
Figure 12	F. Deutsch curb-climbing device
Figure 13	Locke curb-climbing device
Figure 14	Vessa power chair and curb-climbing device

FIGURE 9 AZTEC, DROPBACK DOLLY CURB-CLIMBING DEVICE

FIGURE 10 SUN INDUSTRIES WHEELCHAIR AND CURB-CLIMBING DEVICE

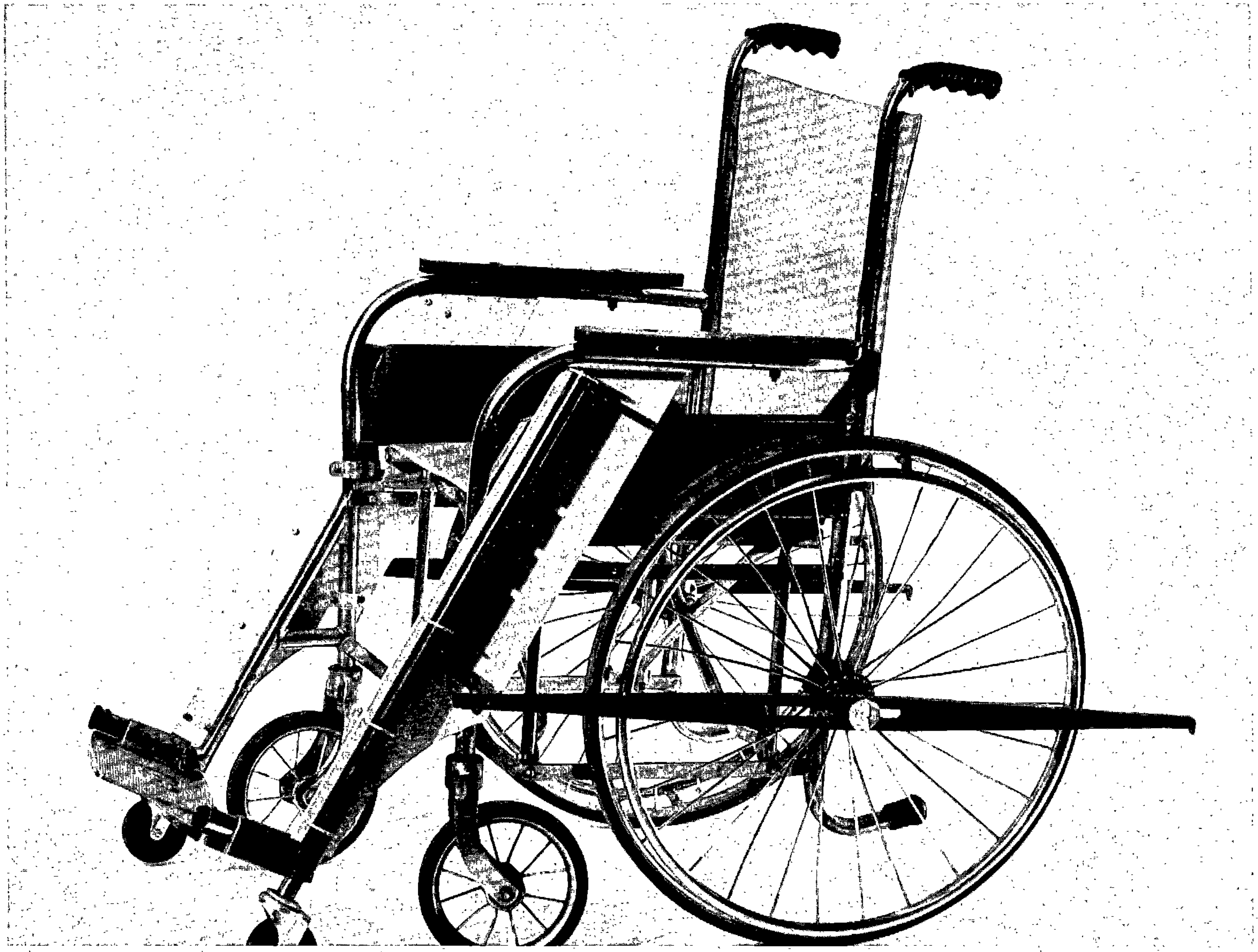


FIGURE 11 PRORECO CURB-CLIMBING DEVICE

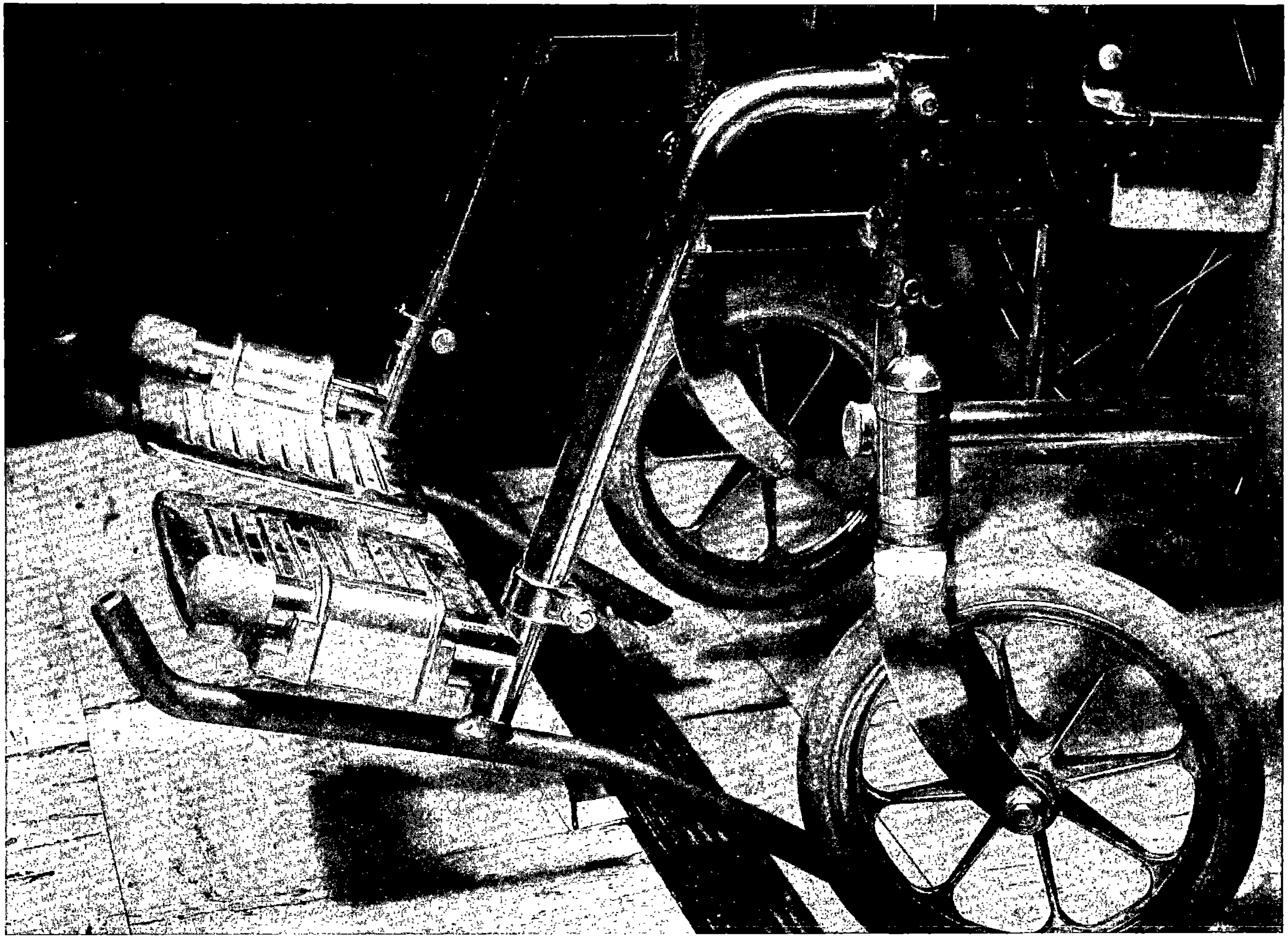


FIGURE 12 F. DEUTSCH CURB-CLIMBING DEVICE

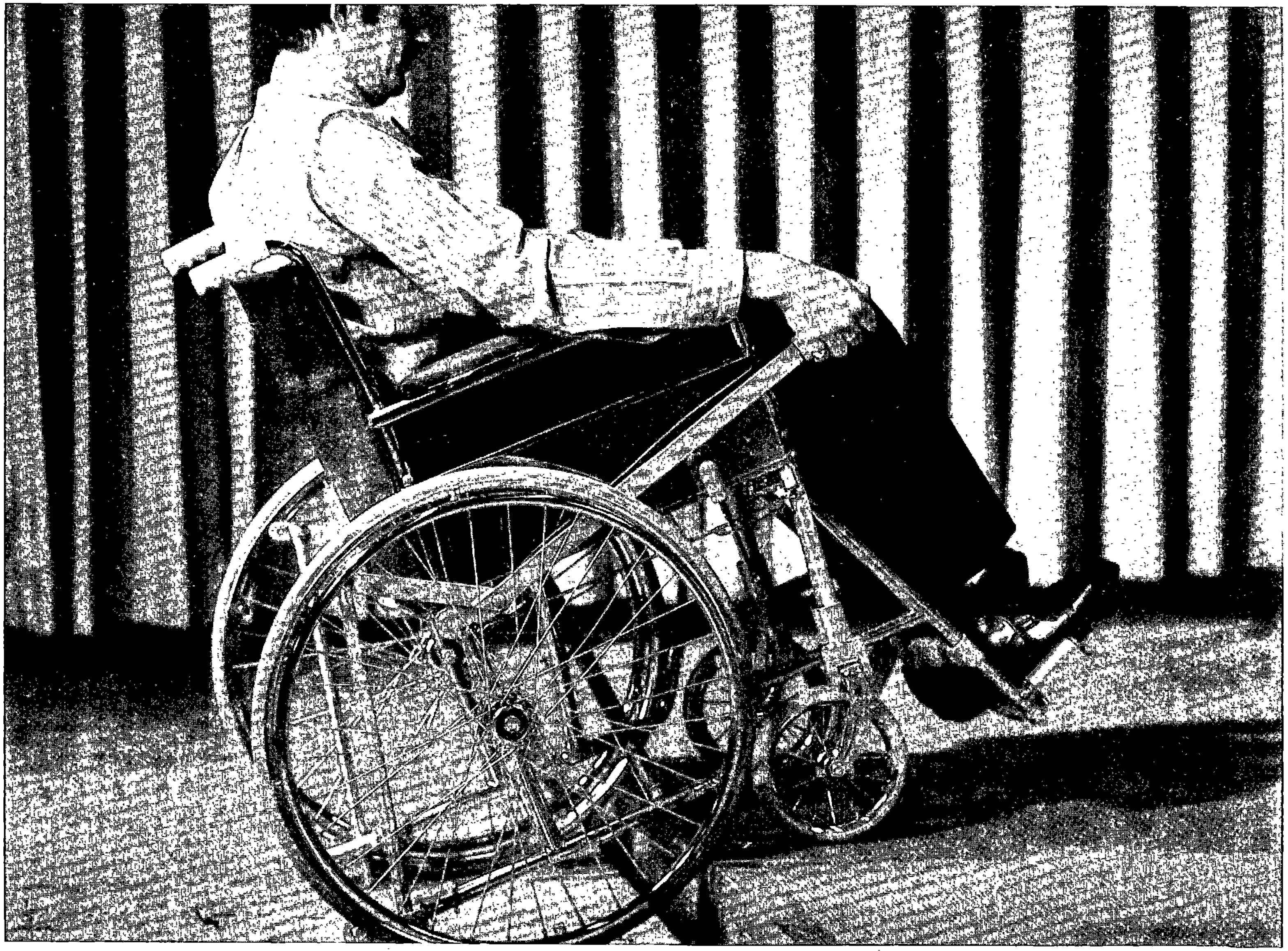


FIGURE 13 LOCKE CURB-CLIMBING DEVICE

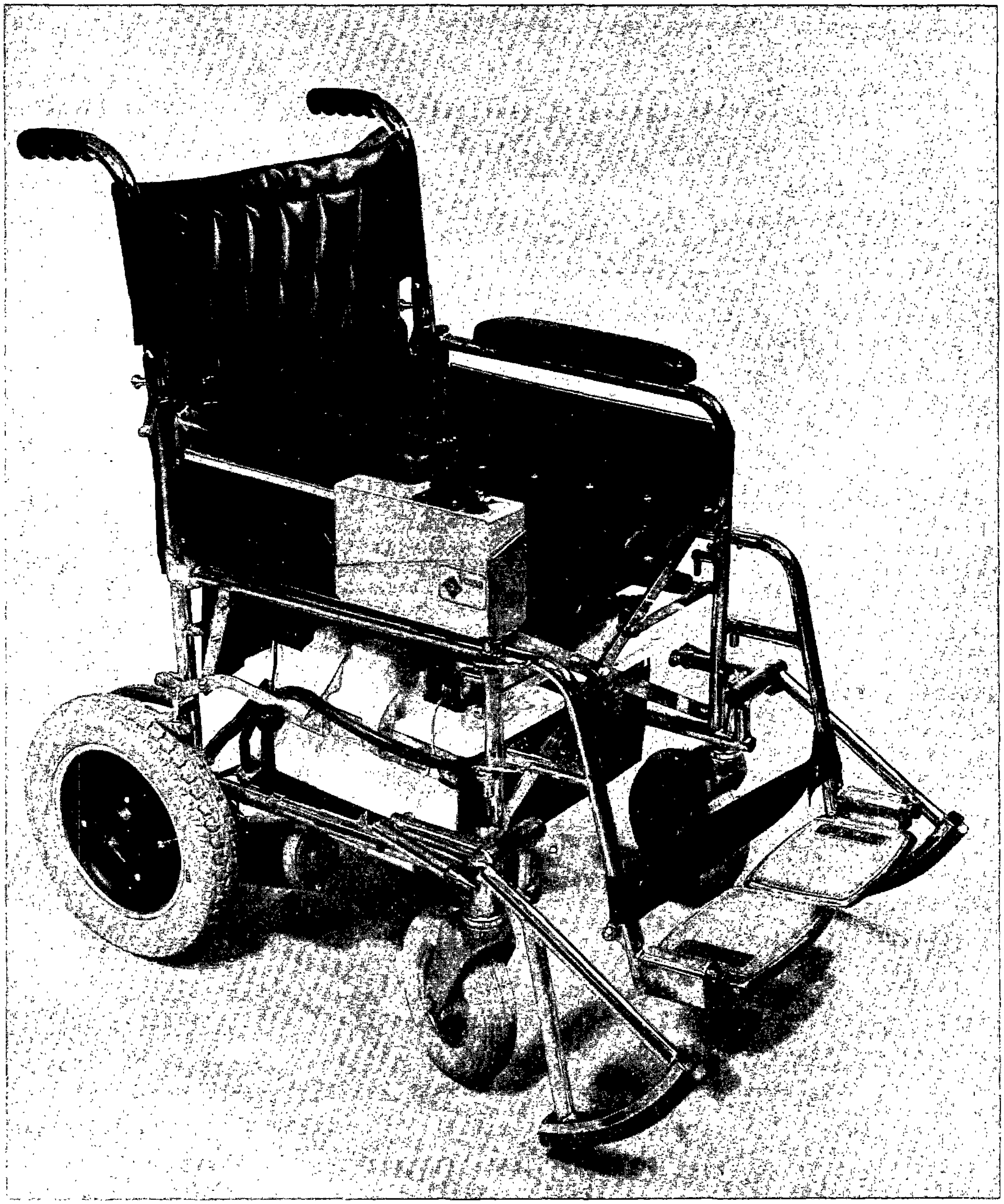


FIGURE 14 VESSA POWER CHAIR AND CURB-CLIMBING DEVICE

APPENDIX A

REPORT OF NEW TECHNOLOGY

For the first time, this report illustrates that quantitative gap-crossing data has been collected on groups of handicapped wheelchair-bound individuals. In order to collect the data, a fixture to simulate horizontal and vertical gaps was designed and constructed by the Veterans Administration Rehabilitation Engineering Center. The data has determined that wheelchair technique and experience is more important than level of disability.

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